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OPERATIONAL DECISION AIDS: A PROGRAM OF APPLIED RESEARCH FOR NAVAL COMMAND AND CONTROL SYSTEMS

H. Wallace Sinaiko

July 1977

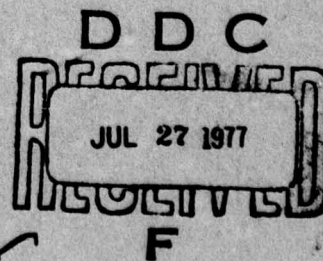
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Smithsonian Institution

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| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Operational Decision Aids (ODA) Project of the Office of Naval Research is reviewed as to its objectives, history, approach, and progress; the con- tributions of its contractors are reviewed as well. Main elements of the project include support activities (e.g., the development of tactical warfare scenarios, case studies of command and control systems, and the provision of a general purpose laboratory test facility) and prototype decision aids (e.g., "outcome calculators," innovative displays of risk in tactical decision- making situations, and automatic alerters or warnings). | | |

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The ODA project is also discussed with regard to how well its objectives have been met. A number of issues are raised having to do with use of decision aids in task force operations. The importance of experimentation with the prototype aids is emphasized.

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**OPERATIONAL DECISION AIDS: A PROGRAM
OF APPLIED RESEARCH FOR NAVAL COMMAND AND CONTROL SYSTEMS**

**H. Wallace Sinaiko
Manpower Research and Advisory Services
Smithsonian Institution**

July 1977

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ACKNOWLEDGMENTS

This paper has not been an easy task, in part because of the diversity and richness of the program it describes and in part because the objectives of the program are complex and without precedent. This document has benefited from the critical reviews of several people, and if the paper is useful, it is because of the time they were willing to commit to reading early drafts and arguing about its contents. I want in particular to thank Martin A. Tolcott, J. Randolph Simpson, and Marvin Denicoff—all of the Office of Naval Research, all scientific officers for portions of the program, and all vociferous and articulate spokesmen for what they believed the paper should address.

In carrying out her secretarial role Carol Blair handled the very demanding details of helping to compile materials and of preparing the manuscript for publication without losing her cool or her smile. Becky Graham, administrative assistant, served as editor with her usual high standard of excellence.

In the end, of course, the buck stops with the author.

H. WALLACE SINAIKO

INTRODUCTION

This paper is about the Operational Decision Aids Project of the Office of Naval Research. It is intended to provide an overview of ODA: its objectives, history, approach, and progress; and its products and how they relate to one another. (A separate memorandum containing a critical review of contractors' progress as of mid-December 1976 has already had a limited distribution.)

BACKGROUND

ODA came into being in mid-1973 as the result of an initiative by four ONR programs. The objectives of ODA were to bring to bear several disparate but related technologies on the development of Navy command and control systems. More specifically, ODA promised to address issues having to do with decisions made by relatively senior officers and their staffs, e.g., task force commanders. Program managers at ONR were aware of a long and not always satisfactory history of R&D aimed at automating certain elements of naval command and control systems. What was different about the present effort was its emphasis on recent technical developments in four areas—computer science, decision analysis, systems analysis, and organizational psychology.

The approach to realizing these objectives has been to contract for specific developmental products with about a dozen R&D companies, one in-house laboratory, and one university. A small steering committee consisting of the ODA Program Manager and four other scientific officers at the Office of Naval Research, with non-voting representation from Op-987, Op-943 and the Naval Electronic Systems Command, provided overall direction. The day-to-day monitorship of individual contracts was handled in the traditional ONR way. The Steering Committee met about once a month; less frequently, a larger coordinating committee was convened. During the first three years of the program, there were intensive semi-annual meetings at which all contractors gave formal presentations of their work. There have also been a few public talks about the program, e.g., at a symposium sponsored by the Air Force on command and control R&D.

The underlying rationale for all ODA work has been the assumption that all products of this program would be subjected to experimental test. Tests were to be undertaken at first by the various contractors in their own facilities, and later at a designated test bed that would serve the

entire program. Ultimately, as various decision aids or other products moved toward fleet use, they would be tested in operational settings by appropriate Navy agencies.* In summary, it is important to emphasize the experimental basis for the entire program, particularly for those developments that could become decision aids in one form or another.

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Contractor members of the ODA program can be considered as falling into either of two categories: a) those providing supporting or context-setting material for the program, b) developers of specific decision-aiding displays, procedures, and techniques. The following pages deal with each group in some detail.

PROGRESS AND PRODUCTS

Support

A half-dozen separate efforts have been directed toward support activities. That is, a significant proportion of the ODA program has concentrated on various context-setting objectives that would later be applied to actual decision aids that were developed. The support activities—described in this section—produced:

- a taxonomy of decisions and warfare scenarios;
- representative and realistic data bases;
- a measure of effectiveness for decision aids;
- case studies of command and control systems;
- guidelines for introducing new decision systems or aids into existing organizations;
- a general purpose laboratory test facility.

1. Decision taxonomy and warfare scenarios

Very early in the ODA program it became apparent that any decision aids that would be developed would have to be tested in a realistic context of political-military situations. It was also apparent that a common knowledge base dealing with the nature of naval tactical decisions would have to be provided as a background for the contractors who would be developing specific aids. What are tactical decisions? who makes them? what are the time constraints under which decision makers operate? what is the physical environment in which task force commanders traditionally work?

* Informal arrangements have been made for ODA testing to be moved to the ARPA/Navy advanced Command Control Architectural Test facility (ACCAT) in San Diego.

The Naval Warfare Research Center of the Stanford Research Institute has made two contributions dealing with these and other questions. First, NWRC developed an analytically-based taxonomy of naval tactical decisions.* Three decision phases were defined, i.e., planning, execution and evaluation; and 32 subsets of decision types were enumerated, e.g., assigning responsibility, selecting targets, etc. Typical task force organizations were described with particular emphasis on information flow. This first NWRC analysis produced, in addition to the descriptive material already named, some interesting and serendipitous insights. For example, task force commanders rarely work in real time; instead, they concentrate most of their attention on advanced planning. This suggests that decision aids need not emphasize instantaneous response rates. Task force commanders are deluged with information in the form of messages, so that improving or increasing communications flow is not indicated. The element which is not handled well by task force command systems is that of uncertainty. Furthermore, high level tactical decision makers are highly idiosyncratic in their approaches—a fact that has too often been ignored by system designers, who more often than not constrain flexibility rather than enhance it. A great deal of attention will have to be paid to the process of introducing new decision aids into existing naval systems.**

The first contribution of NWRC, the proposed taxonomy, was followed by a review of a large number of decision aids and an assessment—analytic rather than experimental—of their applicability to the task force commander's role. Some 36 aids were included, ranging from check lists to speech recognition systems, and an attempt was made to assess each in a quantitative way. The intent of this work was to determine priorities by which the ONR managers could order their developmental program. For example, high priority was urged for a "brief decision analytic aid" that would combine utility theory, value assessment and probability assessment, and the use of decision trees; another aid high on the priority list was warfare simulation modeling. Checklists were also put forth as a low-cost, high-payoff class of decision aid.

The second thrust of the NWRC support work was aimed at developing realistic political-military scenarios with which the decision aids produced in the program would have to cope. Two scenarios were built, in considerable realistic detail, in order to provide decision contexts involving: a) strike warfare and, b) amphibious operations. In the former case the task force commander is confronted with a large number of decisions

* Henceforth, the term "tactical decision" refers to a decision made at the level of the task force commander.

** See Payne, J.R., et al., The Naval Task Force Decision Environment, NWRC-TR-8, September 1974, and Payne, J. R., et al., A Brief Survey of Potential Decision Aids for the Task Force Commander and his staff, NWRC-RM-84, August 1975.

correlated with the taxonomy mentioned above; i.e., he faces a number of realistic preliminary planning options and several execution decisions. The scenarios are built to provide some uncertainty, and there is sufficient flexibility of outcome to permit several repeated runs of each scenario. The scenarios are hypothetical, of course, but their rich detail has been drawn from real events and real places.*

2. Data bases

In order that the scenarios prepared by SRI could become the basis for demonstrating and testing the decision aids produced in the program, it was necessary to provide appropriate information in the form of data bases. This task was undertaken by CTEC, Inc., and it has been operating continuously. (Data bases are the files containing the detailed information, in a form suitable for automatic storage and retrieval, necessary to make the warfare scenarios realistic and capable of execution. For example, one of the ONRODA** scenarios refers to certain enemy aircraft; the associated data base would contain performance characteristics of the particular aircraft, along with information about its vulnerability, fuel capacity, sortie rate, and so on.) In defining data requirements, CTEC worked with other contractors in order to understand the demands their particular decision aids would make of an information system. They also drew on the characteristics and contents of a large number of extant naval tactical data bases.*** Although it would have been desirable to produce data files "containing all the information a task force commander might wish to use . . .," the files that were actually developed were somewhat constrained by resources, by the realities of the ONRODA scenarios, and by the desire to conduct this phase of the program in an unclassified environment. Ultimately some 17 major data files were defined, including: "operations area," "logistics," "weapons characteristics," "enemy intent," and so on. The files were of three general types: a) the "initial data" that a task force command system would possess at the start of the ONRODA scenario, b) "incremental data," which involves conditions undergoing change not under the task force commander's control, and, c) decision-dependent data, which stems from the actions of the commander during experimental operations.

* See Payne, J. R., and Rowney, J. V., ONRODA Warfare Scenario, NWRC-RM-83, June 1975; Rowney, J. V., Supplement to ONRODA Warfare Scenario, NWRC-RM-90, March 1976; and Rowney, J. V., Amphibious Warfare Scenario, NWRC-RM-86, October 1975.

** An acronym from ONR Operational Decision Aids.

*** Interestingly, several deficiencies turned up, e.g., inconsistencies in the labels given to data elements and major gaps in the coverage accorded some U.S. weapons and platforms.

CTEC has continued to define and compile files of "variable data factors," such as tables of weapon coverage, damage assessment of ships as a function of enemy action, and tables of engagement statistics. In addition to the aforementioned files, which were delivered to the University of Pennsylvania in late 1976, new files are being built to contain data required by particular contractor aids; e.g., the emission control planning aid of the General Research Corporation (described in a later section) needs detailed information on the physical characteristics of U.S. Navy radars. In order to provide data that will permit Pennsylvania to exercise its data base management system, CTEC has built files that are appropriate to the Penn network approach. Still continuing is CTEC's work in supplying sensor coverage data (i.e., radar algorithms) and other information as the need arises. In a sense, the CTEC contribution provides the commonality, both generic and specific, needed to compare the relative efficiencies of the many decision aids being generated by other contractors. It may also be possible to employ these ODA data bases as standards by which other naval information systems can be measured. And not the least of CTEC's contributions is the likely disciplining effect on the entire program to the end that different elements, i.e., contractors, will confront a single data base rather than one that is idiosyncratic to their particular decision systems.*

3. Measuring the effectiveness of decision aids

From its inception the ODA program had a strong commitment to the conduct of experiments that would provide quantitative evidence about the various decision aids being developed. For this reason a special effort was initiated with Analytics, Inc., to "develop and analyze alternative methods for measuring the performance of existing and proposed decision aids"** Recognizing the very difficult problem of developing a measure of effectiveness for an element of the task force command center in which people and their equipment interact in a little understood, highly complex way, the contractor sought to provide a method that would be statistically reliable, objective, and capable of extrapolation from laboratory to real-world conditions. The first effort sought to formulate a completely comprehensive basis for measures of effectiveness; this, it was hoped, would suit all possible aids and all aspects of a task force commander's decision functions. After review by the ODA Steering Committee the approach was abandoned as too general, and a new emphasis was proposed. The decision function ultimately selected, which became the basis for the proposed measure of effectiveness that was developed, was information storage and retrieval. In essence the measures developed were two: a) gain in information retrieved and b) rate of gain as compared to random

* For more detailed documentation of the data files prepared by CTEC, Inc., see their ODA Data Base Final Report, 27 Feb. 1976.

** ONR Procurement Request dated 20 November 1974.

processing. Put another way, the measure of effectiveness would indicate the relevance of retrieved information and the amount of time taken to retrieve it; the measure can be expressed as the ratio of relevant-to-total-information retrieved. The analysis which led to the contractor's choice of this measure makes it possible, in the experimental comparison, to show that the performance of decision aids interacts with the time available to use them. That is, a particular aid might produce more relevant information early in the overall decision process; but given enough time, a competing aid might outperform the first. In the contractor's words, " . . . rapid solutions tend to ignore detail and consequently have lower asymptotic values while highly refined solutions, possessing a great wealth and richness of structure, require more time to execute."* The measure derived by Analytics has not been applied experimentally—at first because none of the aids under development was at a state that would permit valid testing, and later because the measure was seen as impractical to apply and its use was suspended.

4. Case studies of operational decision aids

There is nothing new about the concept or practice of enhancing naval tactical decision-making with automated aids. Fairly recently—early in 1976—the ODA program managers initiated a contract that would examine currently operational systems employing decision aids as a means of better understanding the successes and failures of such systems. It was believed that a careful "lessons learned" approach would provide useful insights into the attributes of existing aids that either promoted or inhibited their adoption and performance. The System Planning Corporation (SPC) undertook a nine-month study that examined these areas: a) levels of sophistication of selected decision aids, b) problems in adopting decision aids and how they were resolved, c) successful uses of aids, and d) approaches to the transfer of decision aiding technology from R&D to operations. The SPC investigation addressed these issues in the context of three tactical command and control systems: the Navy's Trident defensive command and control system, the Coast Guard's Vehicle Traffic System, and the Army's Simulated Tactical Operations System.

The Trident's automated display is a sophisticated decision aid which permits the commander to explore various tactical options. Unlike some of the aids being developed in the ONR program, the Trident system is limited to highly structured, repetitive situations, i.e., tracking anti-submarine weapons. The development of the Trident display was modular and evolutionary; that is, the display, although computer-generated, appears to be like more conventional, manually-produced displays.

The Vehicle Traffic System (VTS) is used by the Coast Guard to monitor ship traffic in San Francisco Bay and to provide collision avoidance

* Analytics, Inc., Measuring the Performance of Operational Decision Aids, Final Report 1161-B, 30 April 1976, p. 3-14.

information to pilots and masters. The system is similar to Trident in that the repertory of possible decision actions is limited. It differs from the Trident displays in an important respect: the new Coast Guard system fully supersedes its manual predecessor and does not attempt to be evolutionary. The SPC investigators found that there was an initial reluctance to accept the new system on the part of its operators. At first, the manual system was run in parallel with VTS. A critical event in which the older version failed and the VTS was able to fill in; however, led users to accept VTS. Several attributes of the VTS development are cited as significant: a) although design engineers felt that the system should display only processed information, a raw radar display was provided as well as a filtered picture because operators said that they needed access to all the surveillance information being received; b) the VTS displays and consoles were made to be aesthetically appealing; c) a great deal of attention was paid to providing a system that was easy to learn to use; and, d) there was extensive and continuous interaction between system designers and the people who were to eventually operate and maintain VTS.

The Army's SIMTOS is not an operational tactical system; it is rather an R&D test facility not unlike the intended ONR ODA test bed being installed at the University of Pennsylvania. (See below, p.10.) The principal emphasis of SIMTOS is on testing data access and retrieval methods using a computer, interactive terminals, and experienced Army operations officers as subjects. The latter serve as decision makers in situations set up to simulate the planning and execution phases of warfare operations in Central Europe. Operations officer subjects have full knowledge of the status of both friendly and enemy forces; there is no uncertainty, nor is it necessary for the system to filter or evaluate information. The latter is seen as an unrealistic attribute of SIMTOS. Other continuing problems have been difficulties in defining data elements, problems of deriving measures of effectiveness, and certain incompatibilities with existing operational organizations in the Army. Like the Coast Guard's VTS, SIMTOS designers set out to incorporate principles of ease of learning and operating the system; they also stressed the aesthetics of SIMTOS displays and consoles.

What is the significance of SPC's case studies for the ODA program? One is that none of the decision aids that were examined depart very much from the older systems they have replaced. This is particularly true for the displays of Trident and VTS. Another point is that human decision makers in these systems remained as central elements and their traditional modes of operating were not drastically changed. It is important to keep in mind that the organizational levels studied by SPC were considerably lower than that for which the ONR aids are intended. Thus it is probable that task force commanders would be even more likely (see below, p.10) to demand that departures from systems with which they are comfortable and experienced be relatively minor. The staff of SPC reports an extreme reluctance to automate decision aids to the extent that utility

theory or decision theory is involved. In fact, there seems to be a general reluctance to incorporate automation into tactical decision systems, even in the face of the ever tightening time constraints facing these systems.

On the subject of adapting new aids into larger operating systems, the SPC investigation makes the point that some tactical systems are developed independently and their designers fail to take into account interface issues. The rare cases in which this does not happen, e.g., Coast Guard's VTS, are characterized by close cooperation throughout the development cycle between planners and operating people.

Another important observation, and one that flies in the face of an earlier point, is that there appears to be an overabundance of tactical data being generated. The technology of filtering and processing is certainly available and understood; but the resistance to using it (see above) is what has not been overcome.*

5. Introducing new decision aids and their impact on Navy organizations

It is a well known but little documented fact that the introduction of automated elements into organizations causes considerable turbulence. Sometimes these events have the unhappy ending in which the intended decision aid is rejected and discarded completely, and sometimes (rarely) the aid is successfully adopted—although never without a cost. In an attempt to understand the organizational perturbations which occur when automation is brought to command and control systems, the ODA program management commissioned research by CACI, Inc. The work had these main objectives: a) to review what is known, in a general sense, about organizations and how automated information systems impact on them; b) to conduct case studies of automated naval systems to learn how the work of high level commanders and their staffs has been affected by the automation; c) to develop hypotheses that could become the basis for experimentation with the decision aids being developed by the other contractors; and d) to define strategies for reducing resistance to change and for assuring that aids do get adopted.

The CACI investigators worked from the assumption that a typical task force commander is supported by a staff of about twenty officers, the flexibility of whose roles depends on both the mission to be performed and the idiosyncratic style of the commander himself. The latter is an important point and it underlies the main objective of this part of the ODA program: to learn how the staff organization can be designed to fit a particular commander when automated aids are introduced.

* See Lucas, G. and Ruff, J., An Investigation of Operational Decision Aids, June 1977.

CACI dealt with both formal and informal aspects of organizations. (The former are officially prescribed structures: patterns of authority and responsibility and accountability; the latter are the relationships that evolve among people in organizations.) Formal structure has to be able to accommodate automated decision aids in three ways: a) placing them physically; b) establishing new roles, e.g., those of technicians and operators; and, c) placing the decision aid operators in the hierarchy. Choices have to be made in each of these areas; for example, should current staff be retrained as operators or should new specialists be added to the staff? The informal structure of a staff takes into account the degree of delegation of authority, degree of centralization of leadership, and the nature of interpersonal communication.

In its review of the literature of organizational behavior, CACI found both inconclusive and ambiguous statements about how decision aids affect organizational structures. This led to the investigators' development of their own model for determining the most appropriate organizational structures for technical (i.e., automated) environments. The model says that the form of an organization should be contingent upon its mission, its staff, and the technology available to the staff. Using the model as a basis for designing different organizations, it is possible to hypothesize which are most likely to accept technical innovation and which are not. The model also assumes that the single most important factor in building a naval task force command organization is the style of the commander. One of the products of the CACI work is a set of hypotheses that propose optimal organizational structures for different leadership styles and functions. The hypotheses are carefully defined so that they can be used in an interim sense, i.e., in specifying experimental conditions for test purposes, or in recommending ways to install decision aids with a maximum chance of acceptance. For example, if a task force commander has had little or no exposure to automated aids, specialists should be assigned rather than the commander's staff trained; if on the other hand a commander has had experience with computers, models and decision analysis, it is best to put aids directly under his control and not to install an intervening specialist. The model also stresses team, as opposed to individual, training and experimentation.

The case studies by CACI dealt with four Navy systems: a) the Naval Tactical Data System, which has been used operationally for 15 years; b) an ad hoc, computer-based system (Outlaw-Hawk) that combined ocean surveillance information, an automated management information system, and NTDS inputs; c) the automated management information system (AMIS) used by the officer-detailing activity of the Bureau of Naval Personnel, and d) a developmental fleet command center (FCC) that is intended for use in making strategic decisions in a shore-based operational control center during crisis situations.

Coming out of the case studies were a number of consistent themes, all of which have implications for the aids being developed in the ODA program. First, a most neglected aspect of introducing new automated

decision elements is the development of training and implementation plans; such strategies are rarely given much thought, and few resources are made available to support them. Another common finding was that automatic aids created an environment that centralized decision making in the command authority himself, although this is not necessarily the most efficient organizational model for solving problems. It was also found that each of the systems would have benefited if two coordinators had been provided: a technical administrator, and an "integrator" who would serve as interface for the commander and the automated aid. CACI showed, too, that there was an initial resistance to aids that appeared to be superseding traditional human judgments; such a reaction can have negative effects on morale and cause performance inefficiencies.

The CACI work has implications for all of the decision aids being developed in the ODA program. First, it suggests that a great deal of attention has to be paid to accommodating the aids to individual styles and preferences of the officers who are to use them. This is all the more important because of the high level, i.e., task force command, being served by ODA. Second, the experiments that are to be done with the aids should, in part, include teams or staffs rather than relying exclusively on individual "one-man, one-machine" designs. Third, attention should be given to careful planning for the introduction of the aids. (One suggestion made by an experienced naval officer during a presentation of the CACI work is to re-label decision aids as "analytic" aids so that there will not be an appearance of usurping commanders' prerogatives.) Fourth, and finally, the concept of demonstrating new decision aids should be supported as a separate activity in its own right and as a means of assuring their acceptance or, at least, fair trial.

6. An experimental test bed facility

From its inception the ODA program has made provisions for a central experimental and demonstration site for use by all the contractors. The Department of Decision Sciences, University of Pennsylvania, has had the responsibility for planning and building a test site that is intended for use by all ODA contractors.* As is necessary in such dual purpose facilities, the test bed includes both the necessary equipment—displays, terminals, and communication links with remote computers—and means for conducting experiments, i.e., software that permits logs to be kept for recording the actions of people who serve as decision makers in experiments.

The test bed is located in the Department of Decision Sciences and it consists of 700 square feet to be used as a laboratory. Sometimes

* The Pennsylvania group has another major responsibility, i.e., the development of aids, displays, and data management techniques. That work will be described in a later section.

referred to as a "decision environment," the facility has been structured as a flexible tool to permit the easy installation and adaptation of decision aids produced by other contractors and to allow locally developed devices and software to be added and tested. The facility provides, for demonstrations and experiments, a "group decision area" that can involve up to 30 viewers. This part of the laboratory includes large Advent projection screen displays, a control console for the experimenter, and other display projectors.

An "individual decision environment" area is intended for experiments with single human subjects. There are two work stations with character displays, associated keyboards, and additional computer control units. Both individual and group areas are sound-proofed and air-conditioned.

The principal equipment used in support of the laboratory is as follows: a) a DEC System 10 computer and a GP 100 terminal; b) a Ramtek display and a PDP-11 computer, both located in another area of the University and used to generate high quality color graphics; c) a network system for linking the base computers; d) two Advent Video beam projectors (for black and white or color displays); e) a color TV monitor; f) a character display terminal (ADDS 460) for showing low resolution material (e.g., bar charts and rough diagrams); g) a "mouse" input device used for pointing, moving, or drawing; h) computer network units (Pennsylvania's Gandalf net); i) a video network to bring in displays generated by the remote computer; and j) a voice synthesizer as well as other more conventional auditory and visual methods of generating alerting signals.

The Pennsylvania test facility will also include provisions for recording the actions taken by decision makers working with the various aids. This will make it possible to compile a history of how different subjects used the same aid and how the aids compared with one another. Because the recorded actions will be stored in a computer, it will be possible to program statistical summarizing and analytical routines so that experimenters can have fast feedback on the results of their laboratory trials.

The Penn test facility has been used, and late in 1976 it served as the site for demonstrating a number of decision aids that were brought in by other contractors.

Decision Aids

The heart of ONR's ODA program, and the source of its main payoffs, is the group of contractors who are developing aids of various kinds. There have been nine separate efforts, and each is described in the following pages. Some of the highlights have been:

- a method for incorporating and displaying risk in tactical decision making;

- applications of decision analysis to naval tactical problems, including the development of special display and input modes;
- new approaches to generating automatic alerters and warnings from large data files;
- techniques for organizing data so that it becomes adaptively responsive to the preferences of different users (i.e., tactical commanders);
- several "outcome calculators" that make possible the very rapid assessment of alternative courses of action facing tactical decision makers;
- ways to generate and display information about the complex emission patterns and interactions of own force electronic radiation, i.e., what might be disclosed to an enemy.

1. Data base management and an alerting technology

The Department of Decision Sciences, University of Pennsylvania, has produced a "Decision Aiding Information System" (DAISY) that is based on management science models. The main component of DAISY is an interactive computer with its associated displays, input devices, and software. DAISY is intended for use in complex decision sequences, and it is organized so that the tactical commander himself can have direct access to and be alerted by the computer. DAISY does not provide *fully automatic decisions*, nor is it intended to develop in that direction. Rather, the system is seen by its builders as a surrogate staff officer who supports his principal, i.e., the tactical commander, by "providing access to distributed data bases, powerful mathematical modeling techniques, and a means of sequencing through the decision process"*

The elements of DAISY are: decisions (choices, which contain information about what has happened earlier; alternatives; and time constraints); a relational data base; models (arrangements of rules for handling data within DAISY); triggers (indicators of events or changes of state in the system); a data base management system to facilitate storage and retrieval; and a user-specified graphics capability which permits the multiple segmentation of a display screen.

The user of DAISY may call up CRT displays of data files, and from them he can instruct the computer to extract information relevant to the decision he is facing. Data management techniques make it possible for large files to be organized and reorganized automatically in response to the areas of interest of the decision maker and in ways to reduce system response time. Alerters or triggers adapt to the unique queries of individual decision makers and automatically call to their attention pending events that are critical. The trigger notion in DAISY is particularly useful and it represents a new departure because it is adaptive; that

* Morgan, H. L., DAISY: An Applications Perspective, University of Pennsylvania Department of Decision Science, Working Paper 75-11-03, November 1975.

is, triggers are themselves responsive to the individual styles of decision makers using DAISY.

Several applications for DAISY are envisioned. For example, the system can be used in a training context in which decision makers would face prepared scenarios and be monitored by DAISY for post-exercise feedback. A series of training runs, with the same and different decision-maker subjects, would make it possible to understand the learning process in tactical situations. Also, training runs would enable data base technicians to better organize their files.

DAISY also has an application to tactical operations planning. The system provides a decision maker the chance to propose alternative courses of action, both his own and those of an adversary, and he may ask "what if" questions. In tactical operations DAISY provides a special feature, a dynamic check list, which automatically monitors the decision maker by calling to his attention the sequential decisions that have to be made.

A few of DAISY's other unique features bear mention because they represent significant advances in automated decision processing systems. One is that DAISY is set up for multiple users who may have to interact through transferring responsibility for decisions to one another. This is possible through switching and scheduling routines which give access to a common data base by several users working at different speeds and at different tasks. One user may, for example, create an alerting condition which triggers an action to be considered by a different user, e.g., a staff officer.

Daisy uses the window display concept* as one form of input and output device. Thus, up to five or more areas may be designated on a CRT for displaying different data sets in list or graphic form; a light pen or the "mouse" mentioned above can be used to designate changes or commands. The user can, in DAISY, move windows around the screen to suit his preferences. Most important, each window provides a display and input mode for separate simultaneous tasks being performed.

DAISY also has provision for a voice synthesizer output that can, via computer-generated simulated voice, signal special warnings in an auditory mode. DAISY includes fine grain color graphic capability. The display of quantitative information can be called up in tabular or bar graph form, for example, and comparisons can be highlighted in color.

* Buneman, O. P. et al., Display Facilities for Decision Support: The DAISY Approach, paper presented to the Second Conference on Decision Support Systems, San Jose, California, January 1977.

Preliminary reactions to DAISY's displays have been favorable. One representative Navy user indicated that he had "finally found a system which matched the way [1] look at information while making a decision . . .".*

2. An aid based on decision theory: displaying time-changing events

One of the most advanced efforts in the ONR ODA Program has been research leading to the application of decision theory to naval tactical command problems. Decision theory provides procedures or models for structuring complex problems into component parts. The models are used to derive decision rules. These rules set up thresholds based on the likelihood of the occurrence of key events which affect the outcome of the decision; as thresholds are crossed or approached, an optimum time to shift to a new course of action is signaled. The main parts of a decision model are: a) formal structure of the decision, i.e., the acts from which choices are to be made and the events that affect the outcomes of the choices; b) the value of each decision outcome, i.e., the decision maker's own preferences among the possible outcomes; and c) probability judgments about uncertain events that will affect the decision outcomes. Decision analysis is based on expert judgments about preferred outcomes and about probabilities of the chance events that can affect those outcomes. Expected values are then computed for each alternative choice and displayed to the decision maker. As events change in time the expected values can be changed and displayed graphically or in tabular form. Displays show how threat changes with new information or changed probabilities. Typically, decision theory application has required the intervention of experienced analysts for problem structuring and to elicit probability judgments. The thrust of the current ONR work in this area is to have a computer serve as an analytic aid.

An ONR contractor, Decisions and Designs, Inc., has taken the basic components of these rather abstract theoretical developments and has built a prototype application to naval tactical decision situations.** The DDI Aid contains three displays. The first shows probability changes over time as they relate to the various possible external situations and to the alternative action decision thresholds. This is done by generating a track or vector in a triangular space. (An equilateral triangle has been used because a three-state, mutually exclusive decision space is assumed; hence, any point in the triangle's area represents the relative probability of each possible situation.) Action thresholds, based on the decision maker's judgments, are used to divide the triangle's state areas; as the probability track approaches each threshold, the more preferred is

* Ibid. p. 11

** See: Brown, R. V., et al., Decision Analysis as an Element in an Operational Decision Aiding System, TR 74-2, Sept. 1974; Brown et al., Decisions Analysis as an Element in an Operational Decision Aiding System, TR-75-13, Nov., 1975; and Peterson, C. R., et al., Decision Analysis as an Element in an Operational Decision Aiding System, TR-76-11, Oct., 1976.

that action choice. Thus, the action alternatives available to the decision maker are suggested by the location of the probability vector, and as it moves he can prepare to shift toward the indicated course of action.

The second display is a likelihood table (or intelligence display) showing data in the system relating to events or situations that can affect the situation assessment; this display contains information that drives the probability vector. The third display shows the values assigned to various outcomes by the decision maker.

The DDI Aid makes possible a variety of "what if" analyses. Thus, the decision maker can change the values he assigns to likely outcomes. Or, he can change his estimate of the impact of different types of information received. As changes are made, their implications are displayed automatically.

The DDI Aid is particularly attractive because it makes it possible to structure multiple uncertainties that are typical in naval tactical operations. Thus, several displays could be generated simultaneously, each showing in the same display mode different kinds of information: e.g., probability vectors for weather forecasts, the enemy's state of readiness, and our force's readiness. The probability thresholds of each display will be updated as one or another level of uncertainty changes.

Because of its unconventional approach to tactical decisions the DDI Aid has raised many questions, and they will be addressed experimentally in later phases of the program. For example: Can it best be used to aid in situation assessment, or option selection, or both or neither? We need to know how to program the displays to deal with realistic scenarios like ONRODA. The nature of an optimal interface of the tactical commander with the Aid is not clear. Will he interact directly or will he be better served by a specially trained staff aide who serves as a link with the DDI Aid? There are a number of human factors questions to be addressed, e.g., what is the best visual mode for displaying uncertainty? How can color serve to encode information in this Aid? How can cognition be aided by the DDI Aid; i.e., what are the impacts of color or shape or number on decision processes? How much time is involved in learning to use and interpret the Aid?

Pending the answers to some of these questions, the DDI Aid remains an exciting but unknown entity as far as operational application is concerned.

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The aid described above does not take into account perceived risk or the degree of certainty a decision maker assigns to the outcomes of actions he takes. Paralleling DDI's development, a supplemental

display was designed and tested experimentally at the Navy Personnel Research and Development Center (NPRDC). The purpose of this work was to determine whether the addition of perceived risk to the DDI aid would affect decision making. The impetus for incorporating risk into the DDI Aid was the belief that a tactical decision maker might want to know about the range as well as the average of the expected utility of decision outcomes.

Tactical scenarios were developed, and officers experienced in tactical operations were trained as subjects. Risk was set as either "high," i.e., serious consequences to own force if the wrong decision were made, or "low," i.e., relatively minor consequences if the wrong decision were made. A special display, the NPRDC Bar Graph, was developed to show the risks as well as utilities and probabilities of outcomes of different courses of action: "By showing the actual utilities and probabilities of outcomes in the display, it was possible to provide risk-related information explicitly at each decision opportunity . . ."*

Results of the NPRDC experiment were equivocal and most were not statistically significant. The incorporation of the dimension of risk into the tactical decision process had relatively little effect on the decision maker's performance. For those subjects identified as "risk averse," however, the DDI Aid did assist significantly in the decision process. That is, the Aid benefited those officers who tend to wish to avoid risk but it hindered those who prefer risk. The reason for this is not clear. Curiously, one experimental condition in which neither aid was provided resulted in the best performance by the risk-preferring officer-subjects. Officers who served as subjects reported that they liked the DDI display and that they could learn to use it quickly; the NPRDC modified aid, the bar graph showing risk, was less well integrated into the decision process.

3. Emissions control (EMCON): decision aiding in the deployment sensor systems

Perhaps the most complex area in planning tactical fleet air operations has to do with electronic sensor information: what do our emissions tell the enemy about our force? what do we know about his deployment? how do our (and his) sensor systems contribute to such knowledge? The General Research Corporation (GRC) has been working on decision aiding concepts that will deal with the hard-to-visualize problem of how electronic sensors interact with one another and what such information contributes to judgments by each side about the other.

* Gettys, C. F. et al., Significance of Risk in Navy Tactical Decision Making: An Empirical Investigation, NPRDC, TR-77-8, December 1976, p. 9.

Planning for EMCON is, at present, a tedious manual task. Staff officers fill in matrices with EMCON policy for each ship and each item of emitting equipment. (Policies may range from complete silence to full use.) The EMCON planner decides, for each ship in the force and for each emitter, what risks are involved—and what advantages are gained—by employing the policies available to him. These trade-off decisions require a great deal of information about a technology that is frequently changed or upgraded, and the burden on planners is considerable. GRC has proceeded toward the development of an automated decision aid for EMCON on the basis of the contention that models can provide indications of the interactions of large numbers of electronic emitters much more accurately than can planning officers working with traditional manual aids. In this application, the computer offers a powerful means for assessing all that is known about many radars (or jammers) and how they interact. The GRC approach has been to consider a range of levels of sophistication in an EMCON outcome calculator—e.g., from an information retrieval system containing the attributes of both sides' electronic equipment and how it performs, to, at the other extreme, a highly sophisticated system that can generate complete EMCON plans. (GRC's principal investigator sees an immediate need for data retrieval and display as a more important priority, however, than the provision of an EMCON outcome calculator.)

In essence the GRC aid* is a way of showing what information the enemy can deduce and how important such information may be. The GRC aid calculates "surveillance quality scores" which include the probability that enemy aircraft will be detected before they reach a defended area as well as the probability of successful attack from a "least defended direction." The aid displays radar coverage contours to assist the electronic warfare officer in understanding the relationship between emissions and detection probability. The aid would provide a task force commander the ability to "see" radiation patterns and to exercise greater control over them. The commander's staff would have to specify probabilistically which enemy platforms and types of electronic equipment are in use. The GRC aid would display "frequency space" in an interactive mode; i.e., the commander or his staff could define various conditions of electronic silence and have displayed the information that might be denied to them. Two main components of the GRC aid are an "emission analysis" model and an "air defense surveillance" model. The former assesses the information given away by our force emissions and the latter determines the price paid, in terms of reduced air defense, for EMCON restrictions.

Remaining to be done, of course, is the further development of appropriate software and display hardware that can make it possible to generate the GRC aid so that it can be tested with representative naval

* What is referred to here as an "aid" has not yet been built or demonstrated except as a simulation.

officers. The prospects for doing this are good and the payoffs for task force tactical command and control in a difficult area are likely to be very high.

4. Decision-making under conditions of uncertainty: a human aid for computers

Working on rules for allocating decision functions among system elements, the Integrated Sciences Corporation (ISC) has conducted experiments to determine the best interface arrangements for men and computers. The thrust of this effort is to determine how best to provide for the incorporation of experienced human judgment into computer-based or algorithmic solutions to tactical engagement problems. Subjects have been trained to "draw" continuous subjective functions on a rather sophisticated display surface as a means of entering their estimates of certain aspects of a tactical situation into the computer. (A pilot experiment established the relative superiority of a track ball input device over a light pen and a joy stick.*) Specifically, in an air strike planning task, surrogate officers were required to estimate an optimal flight path that would minimize the probability of detection by the enemy's sensors and at the same time maximize speed to the target. As is usually the case in planning for actual air operations, the subjects faced uncertainties about the enemy's sensors. It was shown that the subjects' ability to design optimum flight paths exceeded that of a fully-automatic mode and that men's subjective assessments would be a good way to derive tactical models for computers.

Direct application cannot yet be made to the design of a task force command and control system, however, and experimentation is continuing.

5. An "Options Matrix" approach to decision aiding

A critical question in providing automated decision aids to a tactical commander is the extent to which he is willing to accept the recommendations put forth for his consideration. Another question is whether automated aids can provide too much information for a commander to assimilate. The Grumman Aerospace Corporation conducted research that cast some light on these matters.

A three condition experiment looked into ways of generating information which would enable a tactical commander to choose among several alternatives in planning a mission.** One mode provided the

*Irving, G. W., et al., ODA Pilot Study: Selection of an Interactive Graphics Control Device for Continuous Subjective Functions Applications, TR 215-2, April 1976.

**See: Kalenty, C. R., and Lockwood, W. L., Experimental Evaluation of an Options Matrix as an Operational Decision Aid, TR-CSS76-31, March 1976; Kalenty, C. R., et al., Experimental Validation of an Options Selection Matrix and Investigation of Other Display Formats as Operational Decision Aids, TR-CSS77-1, February 1977.

task force commander with information in tabular and graphic form but otherwise unprocessed. (His task was to designate one ship for a special mission in a situation in which many complex attributes of his own force, the enemy, etc., had to be weighed.) Subjects worked in a "command support simulator" which generated large-scale displays of data, geographical distribution of forces, equipment status files, and the like. The subjects could request tabular or graphic data via a console operator-aid.

The second condition included computer-generated checklists designed to call to the commander's attention critical factors that would affect his decision. A selection matrix was also part of this aid, and subjects had to enter weightings or figures of merit for the various factors in making their decisions. The computer then calculated a "best solution" based on the subject's estimates and factor weightings.

The third condition presented subjects with filled-in matrices, i.e., all decision options worked out automatically; and subjects had to decide whether or not to accept these solutions.

The experimental outcomes showed several things. First, when presented only with formatted data but no automated aids, subjects arrived at decisions rapidly but were relatively inaccurate. There were complaints of "too much information" to be absorbed, and subjects felt their decisions had to be based on partial information. Second, the options matrix that provided automatic handling and combining of subjects' weightings enabled the commanders to focus on data pertinent to the decisions they were facing. The fully automated arrangement, however, did not meet with approval, mainly because subjects felt they did not have control over inputs to the computer in formulating decisions. Finally, the experiments underscored the reluctance of tactical commanders to accept computer-generated aids without knowing something about their credibility: who were the systems analysts who generated the basic equations? the operators who supplied input data to the algorithms? and the staff who designed the resulting options matrix? Paraphrasing the words of the Grumman investigators, good tactical decision aids should enable the user to formulate his own decisions and, in doing so, to control the amount of automatic aiding he wishes. "The data displays can, however, greatly reduce the effort that would normally be required . . . for data retrieval, organization, condensation, and assimilation"*

6. An outcome calculator to augment tactical decision making

A very sizable amount of data goes into planning a tactical operation; inevitably, as the battle progresses, classes and subsets

* Kalenty et al., op. cit., 1977, p. 6.

of data interact with one another. The Naval Warfare Research Center (NWRC) of the Stanford Research Institute has conducted analytic studies leading to the development of an automated outcome calculator that may prove useful as a type of aid to the naval task force commander. The NWRC model is based on an air strike warfare mission that was drawn from the scenarios described earlier (see page 3).

The outcome calculator consists of many tables, all of them generated automatically and rapidly, that are designed to take account of these variables: the timing of events, the positioning of own and enemy forces, attrition (both sides), weather, and force composition and capability (own and enemy). Among the tables generated and updated by the outcome calculator are these: seven "background" tables, including weapon platform availability and damage repair capabilities; three "scenario" tables, including own and enemy force descriptions; four "course of action" tables, including operations plans; and four "results" tables, including own and enemy missions accomplished. The task force commander must also furnish various input data, e.g., the optional aircraft mixes, that he wishes to consider.

The NWRC outcome calculator generates projections of losses for both sides, taking into account the factors named above, e.g., timing and weather.

To date, the outcome calculator has been run as a simulation (but without real decision makers involved). The model is said to provide useful information on alternative courses of action in that its algorithms permit "what if" questions to be addressed for many conditions. The extent to which the outcome calculator is ultimately of value will depend on the demonstrated ability of task force command staffs to understand and exercise it. NWRC's algorithm has been shown to be compatible with the University of Pennsylvania's test bed facility, and the next step will be to include it in experimental trials with decision makers.

7. An automated process for identifying factors critical to tactical decisions

"Problem structuring" is the process that identifies and organizes relevant factors as a way of helping a decision maker. The structuring process can facilitate decisions in complex, changing, and uncertain situations of the type likely to be faced by naval task force commanders. It also works to counter irrational decisions and it keeps long range issues in focus where they might be cast aside in favor of near-term factors. Decision structuring can be used in one-of-a-kind decisions for which there are no established procedures or precedents. It provides a "current best estimated" course of action, and the estimate improves as structuring goes forward.

In an imaginative attempt to automate the structuring process, the Decision Analysis Group, Stanford Research Institute, has been developing an algorithm that will enable the task force commander to

build formal decision models. The main output of this work has been a method that identifies important decision factors. (There is an obvious complementarity to the work on triggers or alerters at the University of Pennsylvania, and both groups of investigators have discussed a combined effort.)

As currently developed, the SRI structuring process is based on approximations derived from experimental trials. The SRI process combines human and automated elements in a dialogue format that runs as follows: trade-off judgments about the would-be tactical operation are stored in the computer; these may be pre-planned or they can be developed by the task force commander; the computer generates questions which the analyst interprets to the commander who, in turn, provides answers that are entered into the computer via the analyst; the dialogue proceeds as the computer performs calculations and generates new questions. As this iterative process takes place, a skeletal decision tree expands with more and more detail: outcome probabilities are assigned to chance nodes, and values are generated for terminal points. Thus, expected values for alternative courses are calculated and refined as more detail becomes available.

In the overall structuring process, the staff analyst identifies alternatives, he estimates outcomes, and he provides ranges of uncertainty for each alternative outcome. The commander's priorities or trade-off preferences take the form of a value model. The computer calculates expected values or utilities for each alternative; it also points out areas needing clarification by calculating the value of resolving the uncertainties in the overall problem; and the computer generates new questions that identify events not yet in the model. The staff analyst and the task force commander can postulate additional events for the model, and the computer can estimate whether these events will influence the decision under consideration. If the event is added to the model on the basis of the analyst's assessment, the process continues.

There are a number of unanswered questions regarding SRI's structuring process. The contractor plans to implement a computer model of his procedure and to conduct experiments that will point out areas needing re-work or strengthening. Actual experimentation is to be carried out at the University of Pennsylvania test facility. Three subsystems, none of them yet completed (as of April 1977), are to be built and tested. They are: a) a user-interface subsystem; it provides, prompts, and checks on the appropriateness of user responses; b) a tree-handling subsystem, which generates appropriate decision trees, including decision probability, and terminal nodes; c) a probability distribution fitting subsystem, which converts estimated outcomes and ranges provided by the decision maker into continuous probability distributions.

8. Nomography applied to tactical decision aiding

One of the more recent efforts of the ONR program has been the investigation of nomography for displaying complex relationships among different classes of data. This work is looking into ways to show, simultaneously, many variables that impact on tactical warfare planning, e.g., own force readiness, ratios of friendly-to-enemy forces, weather conditions en route and over the target, desired combat exchange ratios, and so on. The contractor, Analytics, Inc., believes that nomography will enhance the selection of optimal timing for tactics which have already been chosen, such as when to launch an air strike. Another claim that has been made for this approach is that it can deal with dynamic data conditions, i.e., hourly or more frequent changes of information. Uncertainty is also said to be taken into account and its impact shown.

At this time it is not possible to assess Analytics' nomographic work. The approach is promising; but, pending further development and testing with experienced officers, little more can be said.

SOME CONCLUDING THOUGHTS

There is no doubt that the program has been rich and varied and productive. As in other developmental efforts, a great deal of hope was generated that near-term products would be forthcoming and could be incorporated into naval command and control systems, both those in being and those coming on line. There is some evidence that the Naval Electronic Systems Command would like to incorporate some of the ODA output, e.g., certain features of the University of Pennsylvania's DAISY, into its Tactical Flag Command Center now in development. But such developments are slow and they tend to be delayed and sidetracked along the way. Nevertheless, it is encouraging that some of the ONR program has met with acceptance.

A number of the ODA "products" offer further promise. For example, the GRC approach to emission control offers a straightforward way of dealing with the complexities of electronic radiation. The DDI application of decision theory is perhaps the least familiar of the ODA products to operational Navy personnel. As such, it faces the most demanding and skeptical questions of would-be users. This situation can, of course, be eased with experimentally derived evidence of the Aid's effectiveness.

Many questions remain unanswered in the domain of decision aiding. The major issue, and one that has been raised repeatedly, is what will happen when representative naval officers use the aids under somewhat (simulated) realistic conditions. There is evidence that some of the aids present displays and require procedures that depart from conventional

tactical command and control to the extent that users require a great deal of indoctrination. The NPRDC Bar Graph is an example of the latter, as is the DDI display. Another somewhat disturbing finding was that senior officer subjects exhibited considerable anxiety about accepting automatically generated decisions or parts of decisions. It is not enough, in these cases, to propose training as a way out. What must be done is to find ways of displaying probabilistic situation assessments, and probability distributions of outcomes, that will permit the decision makers to conduct their own tradeoffs to reach a decision.

One of the least fulfilling aspects of this program has been its inability to define ways to measure the effectiveness of decision aids. This is part of the more general and very long-standing problem of criteria for command and control. The problem will not be solved by the ODA program, but the program should make some useful contributions to the development of performance criteria for the decision aiding components of command and control systems. This paper has alluded to some possible approaches to the measurement of effectiveness, but much more needs to be done. For example, the question of the quality of tactical decisions arises; i.e., do the aids significantly enhance a tactical commander's performance? Are economies of time or resource allocation realized with one or another of the aids? What are the basic economics of introducing decision aids into the fleet? are there likely to be significant software costs? (Probably.) Are the human resources—systems analysts, programmers, and decision theorists—available to support the aids?

Overall there is a strong need to set up the decision aids—or at least the most promising among them—in a demonstration mode. A great deal of attention should be paid to hardware reliability and to providing understandable demonstrations of what the aids can do. This should not substitute for systematic, careful experimentation, but it would serve the important need of providing familiarization with the aids among a large community of potential users. (ONR staff and its contractors may have been too close to ODA developments to realize just how difficult the techniques are for the uninitiated to comprehend.) In the end, of course, the real payoffs for ONR's contribution will lie in experimentally derived evidence that the decision aids work. This is difficult and expensive experimentation, but it must be done.

There are a number of unanswered questions that are suggested by the work done in the ODA program so far. None of these issues, of course, should have been addressed earlier, nor could they have been without the developmental work that this paper covers. For example, there will inevitably be new costs to the Navy if any of the decision aids progresses to the point of becoming operational. There may be new hardware—displays, data input devices, computers, and the links necessary to incorporate all of these into existing or new command control systems. These costs are bound to be non-trivial, particularly where they involve new technological demands such as color displays (an attribute of some of the aids in the ODA program).

But at least two other kinds of costs loom as even more expensive than hardware. They are, first, the resources necessary to build and maintain the software packages that support the decision aids. We do not have any estimates of the extent of software costs, nor were they included in this inquiry. But fifteen years of experience with the Navy Tactical Data System has shown that extensive software back-up is required.

The second cost, and one that is difficult to predict but is nevertheless an important aspect of adopting decision aids for fleet use, is the time necessary for introducing new technology of this type. Assuming that a decision aid is tested experimentally and that the Navy's system development process marks it for introduction to the operating forces, there will inevitably be long delays before the aid can be expected to be in place and available to task force commanders. The delays due to hardware and software procurement can, perhaps, be minimized if enough priority is assigned to the production effort.

A delay not so easily dealt with will be that which comes about from introducing such new approaches to tactical decision-making as are embodied in some of the ODA aids. What we are referring to are the inevitable perturbations to organizations when some traditionally human functions are automated. There is a growing literature in the management and behavioral sciences dealing with these effects and ways to deal with them. As indicated in earlier sections of this paper, two contractors—CACI and Systems Planning Corporation—have been concerned with change brought about by automation. We believe that these efforts bear serious study and should perhaps be extended. It is our strong conviction that the main barriers to satisfactorily adopting decision aids will be human organizational issues rather than hardware problems.

Have the ODA program objectives been realized? As stated in the authorization document that approved the ODA program, "the essential objective of the work is to improve tactical decision making by blending a number of technologies . . . into a practical system for shipboard use"* The ONR program has brought to bear several technical areas—decision analysis, computer graphics, data management, and organizational psychology—into a single effort. It is too soon to address the issue of whether this program will produce techniques that could be adopted or incorporated into other developmental programs; but, as we have indicated earlier, there has been high interest expressed toward some aspects of the program by the Naval Electronic Systems Command. The significance of that interest will, of course, be demonstrated to the extent that ODA concepts and aids actually find their way into the fleet.

* Navy Decision Coordinating Paper RPN08, Operational Decision Aids, 8 July 1976.

Another objective of the program has been to develop a better understanding of human decision processes and ". . . to integrate (that knowledge) with the enhanced capabilities of new communications and data processing hardware"* In our view, this objective is the most ambitious part of the entire ODA undertaking and, if successful, will far outweigh any hardware contributions the program may bring about. There is still a long way to go to demonstrate that the efficiency of command decision-making processes has been improved; this program, however, particularly with its emphasis on the decision sciences, has undertaken a risky venture which will have high value if it succeeds. Perhaps "success" is a naive concept. All research generates new knowledge in painfully small and costly increments. The ODA work has taken a fresh look at the state of decision technology, and some of its outcomes are innovative and exciting. What remains, and what will undoubtedly be the next phase of this work, are the demonstration and experimental studies that have to be accomplished before one can say much more about program objectives and the extent to which they have been attained.

* Idem.

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